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(54) Title: A SYSTEM AND A METHOD FOR PROTECTING AN ELECTRIC MOTOR AND ITS CONTROL CIRCUIT, AND AN ELECTRIC MOTOR

(57) Abstract

A system and a method for protecting electric motors and their respective control circuits are described, wherein it is possible to distinguish whether a situation of surge current results from a overload or from a short–circuit on the motor (1). This is achieved by means of a system for protecting an electric motor (1) and its control circuit (2), the motor speed control being carried out by means of a set of switches (Ch), the system comprising a control central (7) capable of measuring the electricity conduction time (Tc) of each of the switches (Ch) and to measure the time (Td) passed between the beginning of conduction of one of the switches (Ch) and the occurrence of a surge current, the central (7) making a comparison of said times (Td, Tc) and being capable of determining whether said surge current results from an overload or a short–circuit of the electric motor (1) or on one of the switches (Ch). The invention also refers to a method for protecting an electric motor (1) and its control circuit (2), the speed control of which is carried out by means of a set of switches (Ch), wherein the method comprises a step of measuring the electricity conduction time (Tc) f each of the switches (Ch), a step of measuring the time (Td) passed between the beginning of conduction f on of the switches (Ch) and the occurrence of a surge current, and a step of comparing said times (Td, Tc) and consequently determining whether said surge current results from an overload or from a short–circuit of the mot r (1). In addition, th present invention refers to an electric motor (1) that is controlled by a set of switches (Ch), the control of the switches (Ch) being carried out by a control central (7) capable of measuring and comparing said times (Td, Tc).

Title: "A SYSTEM AND A METHOD FOR PROTECTING AN ELECTRIC MOTOR AND ITS CONTROL CIRCUIT, AND AN ELECTRIC MOTOR"

5   The present invention refers to a system and method for protecting an electric motor and its control circuit, which aims at detecting possible technical failures that cause the current to rise.

An electric motor basically comprises a rotor and a stator. In order for this motor to function, that is so say, for the rotor to start moving, voltage is applied to the stator, inducing the movement of the rotor.

10   Usually, the control of rotation speed of the motor is carried out by means of inverters, which in turn are formed from switches, as for instance a MOSFET (transistor).

The application of electric motors having controlled speed is widespread, being used, for instance, for driving compressors, household appliances, traction, etc.

Basically, when used in permanent-magnet motors without position sensors,
15   the inverters are constituted by a set of diodes for branching the alternate voltage, from a control central that actuates the switches and a block responsible for detecting the position of the rotor by monitoring the voltages in the phases of motor, making a comparison between the monitored values. The control of the motor is carried out by modulating the voltage on the phase of the motor, which consists in applying and interrupting the voltage on the
20   phases at a high frequency. By means of this modulation, it is possible to control the current supplied to said phases of the motor, and one can adjust it at the desired torque and speed for its operation.

In the case of induction motors, the positi n d tector of the rotor is not used, the control of speed and torque being effected by modulating the voltag on the phases of the motor.

In both cases, a control central is employed, which is usually constituted by a
5   microcontroller or a signal processor, which receives the external command for operation of the motor and starting from the monitoring of internal variables of the motor/inverter (current on the motor, position of the rotor, etc.), generating commands that supply voltage and current to the motor.

During the actuation and functioning of the motor, the current may undergo
10   rises (or surge current) as a result of a overload or else as a result of a short-circuit.

The rise of the current resulting from a overload does not immediately endanger the integrity of the motor and can be controlled. However, the current rise resulting from a short-circuit has a very rapid action, and so a protection mechanism should be actuated in order to prevent damage to the motor or the respective control circuit.

15   **Description Of The Prior Art**
The systems and methods for detecting surge current in electric motors known from the prior art usually actuate by using a predetermined current value, that is to say, a maximum current value is predetermined, so that the motor will not be damaged and, once this value is exceeded, a protection mechanism is actuated, protecting the motor or the
20   respective control circuit. However, this protection method does not enable one to differentiate whether the current rise results from a overload or from a short-circuit, causing the protection mechanism to be actuated in either situations.

Short Decription Of The Invention
The objective of the present invention is to provide a system and a method
25   for detecting the occurrence of surge on electric motors and its control circuit, which will enable one to distinguish the occurrence of overload on the motor from a short-circuit, by using only a current detector adjusted to a preferred limit.

This objective is achieved by means of a system for protecting an electric motor and its control circuit, the control of motor speed being carried out by means of a set
30   of switches, the system comprising a control central capable of measuring the electricity conduction time of each of the switches and to measure the tim passed b tween the begin-

ning of conduction of one of the switches and the occurrence of a surge, the central making a comparison of said times and being capable of determining whether said surge current results from a ov rload or from a short-circuit of the electric motor.

5   The present invention also refers to a method for protecting an electric motor and its control circuit, the speed control of which is effected by means of a set of switches, comprising a step of measuring the electricity conduction time of each of the switches, a step of measuring the time passed between the beginning of conduction of one of the switches and the occurrence of a surge current, and a step of comparing said times and consequently determining whether said surge current results from a overload or from a short-circuit on the

10   electric motor.

In addition, the present invention refers to an electric motor, the speed control of which is carried out by means of a set of switches, the control of said switches being effected by a control central that is capable of measuring the electricity conduction time of each of the switches and to measure the time passed between the beginning of conduction

15   of one of the switches and the occurrence of a surge current, the central making a comparison of the said times and being capable of determining whether said surge current results from a overload or from a short-circuit on the electric motor.

Brief Description Of The Drawings

The present invention will now be described in greater detail with reference to an

20   embodiment represented in the drawings, in which:

- Figure 1 represents a schematic diagram of the speed control circuit of the motor and of the surge current detector according to the present invention;

- Figure 2 shows a temporal diagram representing the behavior of the current in a overload current situation;

25   - Figure 3 shows a temporal diagram representing the behavior of the current in a short-circuit situation;

- Figure 4 represents a flow-diagram of the method according to the present invention.

Detailed Description Of The Figures

The system for protecting an electric motor and its control circuit according to the present invention basically comprises a surge current detector 3, adjusted to a determined current limit.

5   Figure 1 schematically illustrates the motor 1 and the respective circuits for its control 2 and feeding. According to a preferred embodiment of the present invention, the motor 1 described will be of the three-phase type, which does not prevent the invention from being applied to another type of electric motor.

As can be seen from figure 1, the motor 1 and its control circuit 2 are fed by a
10   source supplying alternate voltage that will be rectified by a set of diodes D and filtered by a capacitor C_1. A set of switches Ch1 - Ch6 is responsible for the modulation of the voltage on the phases F_1, F_2, and F_3 of the motor 1. The control of the set of switches Ch1 - Ch6 is carried out by a control-central 7.

The detection of surge current is carried out by means of a surge-current de-
15   tecting circuit 3, which measures the current I_{RS} that flows along the circuit through the resistor R_S.

As illustrated in figure 1, the resistor R_S is installed in a position of the circuit that allows one to read the current I_M flowing through phases F_1, F_2, and F_3 of the motor, the current I_{RS} basically representing the current I_M.

20   The control central 7 emits commands for closing and opening the switches Ch1 - Ch6, besides receiving external information, such as the signal D_S, for instance. The signal D_S is generated by the surge current detector 3, when a predetermined I_{LIMIT} value (current limit) is exceeded.

The surge current detector 3 comprises an operational amplifier mounted as
25   a voltage comparator C_O, the inlets of which are fed with voltages "E-" and "E+", wherein "E+" is the voltage of the first terminal of the resistor R_S, and "E-" is the voltage of the other terminal of this resistor R_S, plus an essentially constant voltage, defined by the voltage divider R_A and R_B. The $+V_B$ voltage is a constant.

The resistor R_1 causes the voltage variations on the resistor R_2 (represented
30   by the current I_M of the motor) to be added to the constant voltage defined by the resistors R_A and R_B.

For a situation in which the current I_M flowing through the motor 1 is close to zero, the voltage "E-" is higher than the voltage "E+", thus causing the outlet D_S of the voltage comparator C_0 to be at "low" level.

5   When the current though the motor 1 rises above a I_{LIMIT} limit defined by the resistors R_A, R_B and R_1, the voltage in the inlet "E-" becomes lower than the voltage in the inlet corresponding to a current value beyond the admissible limit, that is to say, above the I_{LIMIT} limit, thus characterizing the detection of surge current. In this situation, the outlet of the comparator C_0 passes from "low" level to "high" level, signaling the occurrence of surge current to the control central 7 by means of D_S.

10   The differentiation between a overload and a short-circuit is made by measuring the rise variation time of the current I_{RS}, i.e., in the event of overload, the current rise occurs gradually, taking a relatively long period of time, until the I_{LIMIT} value is reached, whereas in the cases when the motor 1 enters into short-circuit, the I_{LIMIT} value is reached much more rapidly, thus enabling one to detect this kind of failure by measuring the time.

15   As already known from the prior art, the speed control is carried out by means of switches Ch1 - Ch6 and, as illustrated in figures 2 and 3, the switches Ch1,Ch4 conduct electricity for a determined period of time T_c that varies depending upon the rotation speed to be imposed to the motor 1.

In order to determine whether the kind of failure on the motor 1 results from a

20   overload or from a short-circuit, the present invention foresees the T_c-time and T_d-tim measurement. The T_d-time is counted from the beginning of the conduction of the switches Ch until the moment when the current has reached the I_{LIMIT} value, that is to say, when th surge current occurred (see figures 2 and 3). The T_c-time is the time of conduction of the switches Ch and depends upon the situation of motor operation (basically speed and load).

25   Figures 2 and 3 represent the temporal diagrams of the situations of overload and short-circuit, respectively. By comparing the two diagrams, one can see in detail that, in the short-circuit situation, the current I_{RS} reaches the I_{LIMIT} value in much shorter T_d time when compared with the T_d time in th overload situation.

As can be seen from figure 4 schematically, the criterion us d for determining

30   wheth r th surge current results from a overload or from a short-circuit d pends upon a relation between the T_d and T_c times. Thus, when the relation $T_d < T_c . k$ is true, this means that the motor 1 is in short-circuit, and when the relation is false, this means that the motor 1

has und rgone a overload. The measurement of the T_d and T_c tim s, as well as the comparison between the respective values is carried out by means of the control central 7.

The value of the constant k is a fraction or portion of the T_c value (being a number betw en 0 and 1), and defines the limit for the distinction of the kind of failure that
5   occurred on the motor 1, and may vary depending upon the type of motor 1 in use, in addition to the protection level to be given to the latter.

For instance, if the value of k is 50% (or 0.5) and if the T_d time is short (shorter than 50% of T_c), this means that the motor 1 is in short-circuit, and it is necessary to add some protection mechanism in order to avoid damage to said motor 1. In the cases when T_d
10   is longer (longer than or equal to 50% of T_c), this means that the motor 1 has undergone a overload.

Besides enabling one to differentiate the kind of failure occurred on the motor 1 or on one of the switches Ch1 - Ch6, the present invention further enables one to estimat the value of the surge that occurred on the motor 1 by evaluating the proportion T_d/T_c.

15   A preferred embodiment of the invention having been described, it should be understood that the scope of the present invention embraces other possible variations, being limited only by the contents of the accompanying claims, the possible equivalents being included therein.

Claims

1. A system for protecting an electric motor (1) and its control circuit (2), the speed control of the motor (1) being carried out by means of a set of switches (Ch), the system being characterized by comprising a control central (7) capable of measuring the electricity conduction time (T_c) of each of the switches (Ch) and to measure the time (T_d) passed between the beginning of the conduction of one of the switches (Ch) and the occurrence of a surge, the central (7) making a comparison between said times (T_d, T_c) and being capable of determining whether said surge current results from a overload or from a short-circuit on the electric motor (1) or any of the switches (Ch).

2. A system according to claim 1, characterized in that the occurrence of a surge is detected and signaled to said central (7) by means of a surge detector (3).

3. A system according to claim 1 or 2, characterized in that the control central (7) indicates a condition of short-circuit of the motor (1) or on one of the switches (Ch) when the time (T_d) is shorter than the time (T_c) multiplied by a factor (k) that ranges from 0 to 1, th central (7) indicating a condition of surge of the motor (1) when the time (T_d) is longer than the time (T_c) multiplied by said factor (k).

4. A system according to claim 3, characterized in that said factor (k) is equal to 0.5.

5. A method for protecting an electric motor (1) and its circuit (2), the speed control of the motor (1) being carried out by means of a set of switches (Ch), the method being characterized by comprising a step of measuring the electricity conduction time (T_c) of ach of the switches (Ch), a step of measuring the time (T_d) passed between the beginning of conduction of one of the switches (Ch) and the occurrence of a surge, and a step of comparing said times (T_d, T_c) and consequently determining whether said surge current results from a overload or from a short-circuit of the electric motor (1) or on any of the switches (Ch).

6. A method according to claim 5, characterized in that, in said comparison step, a condition of short-circuit of the motor (1) or on one of the switches (Ch) is indicated when

the time (T_d) is shorter than the time (T_c) multiplied by a factor (k) that ranges from 0 to 1, v overload condition of th motor (1) being indicated when th time (T_d) is long r than the time (T_c) multiplied by said factor (k).

7. A method according to claim 6, characterized in that said factor (k) is equal to
0.5.

8. An electric motor (1) having the speed control carried out by means of switches (Ch), the motor (1) being characterized in that the control of the switches (Ch) is carried out by a control central (7), said control central (7) being capable of measuring the electricity conduction time (T_c) of each of the switches (Ch) and to measure the time (T_d) passed between the beginning of conduction of one of the switches (Ch) and the occurrence of a surge current, the central (7) making a comparison between said times (T_d, T_c) and be-ing capable of determining whether said surge current results from a overload or from a short-circuit of said electric motor (1) or any of the switches (Ch).

9. A motor according to claim 8, characterized in that the control central (7) indi-cates a condition of short-circuit of the motor (1) when the time (T_d) is shorter than the time (T_c) multiplied by a factor (k) that varies between 0 and 1, the central (7) indicating a condi-tion of overload of the motor (1) when the time (T_d) is longer than the time (T_c) multiplied by said factor (k).

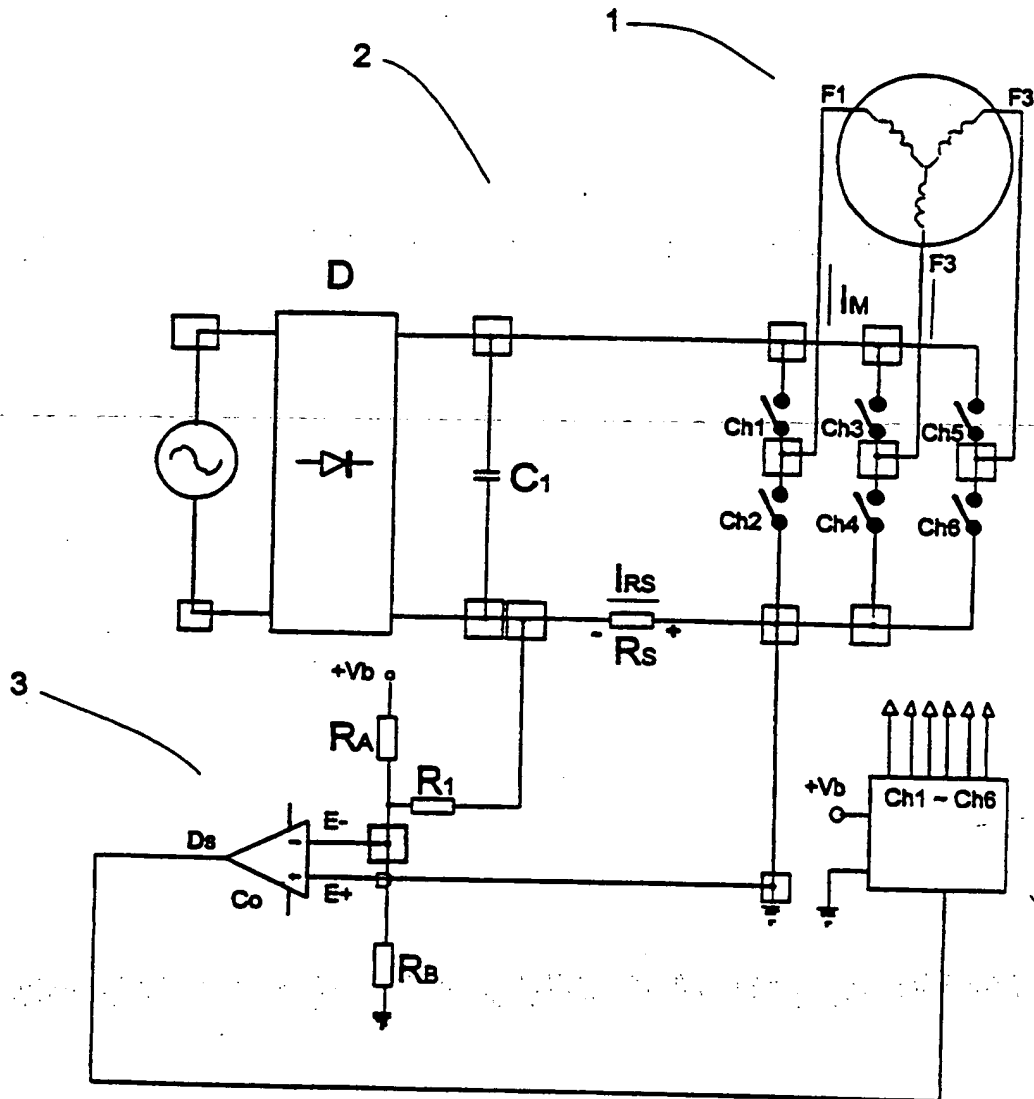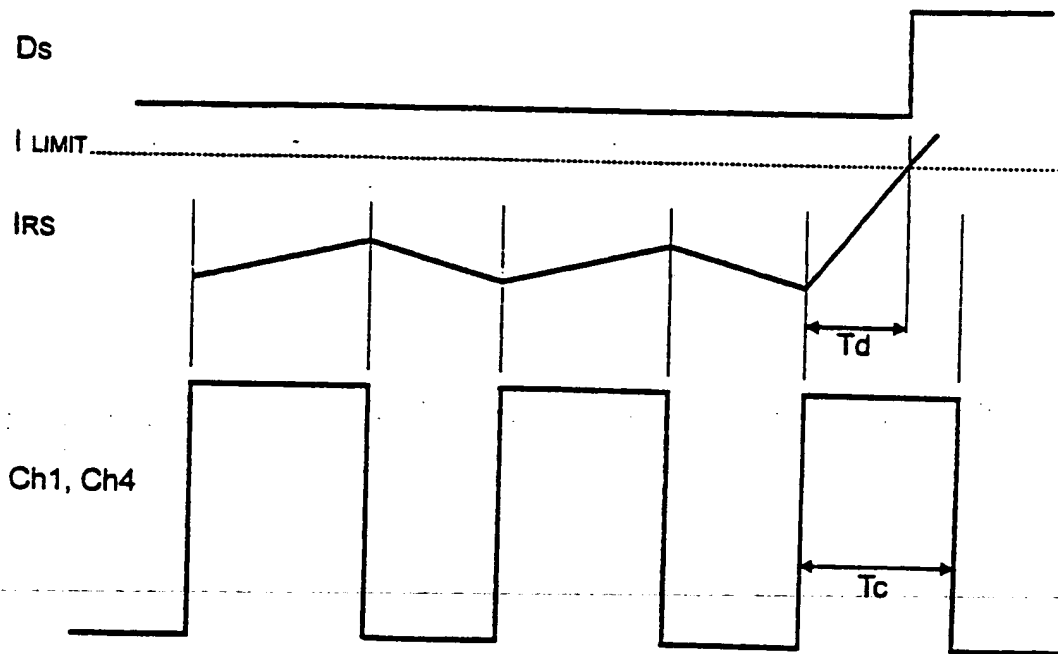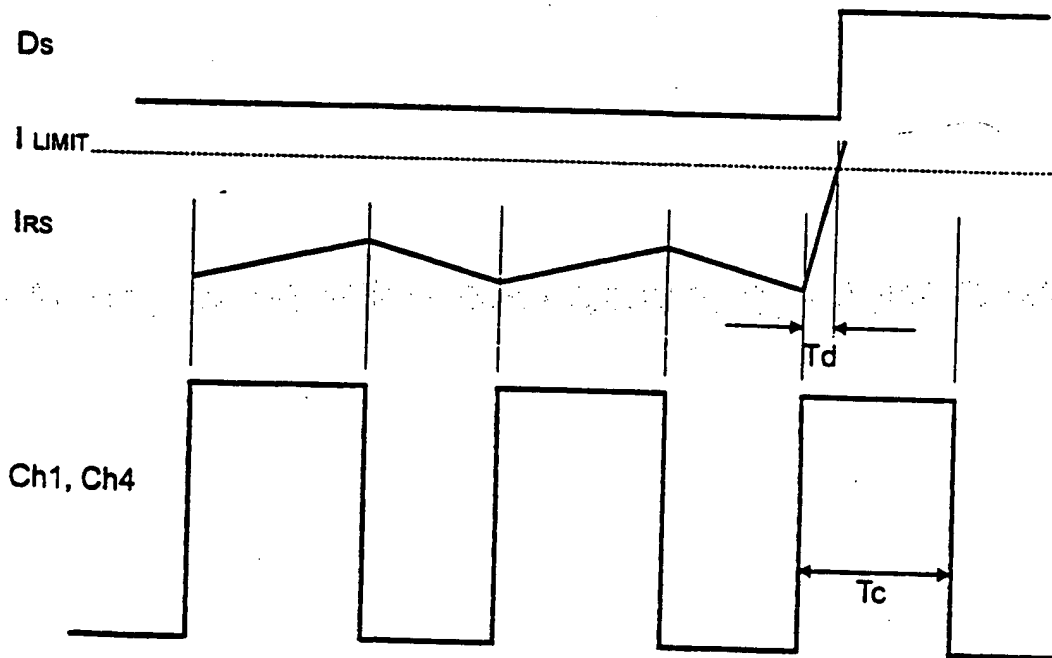10. A motor according to claim 9, characterized ion that said factor (k) is equal to
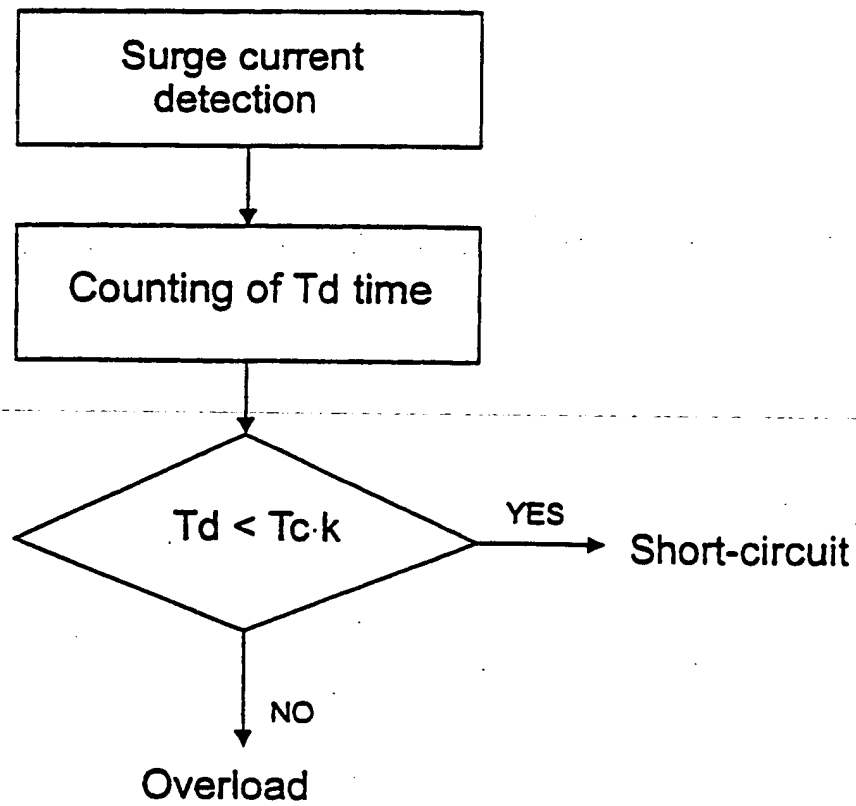0.5.

FIG. 1

Ds

I LIMIT

IRS

Ch1, Ch4

Td

Tc

FIG. 2

Ds

I LIMIT

IRS

Td

Ch1, Ch4

Tc

FIG. 3

FIG. 4